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AGE OF FLOATING ICE.

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THE AGE OF FLOATING ICE IN NORTH WALES.[1]

By D. MACKINTOSH, F.G.S.

Sea-coast Fringe of mixed Local and Northern Drift.

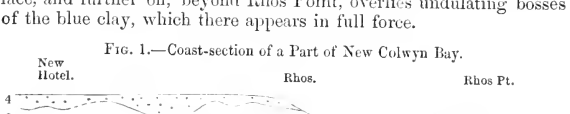
WITHOUT occupying valuable space with introductory remarks, I would begin with a description and attempted explanation of the drifts along the coast of Rhos Bay, or what is now generally called Colwyn Bay. Well-sinkings, clay and gravel pits, and coast sections, very clearly reveal a quadripartite arrangement of drifts similar to what may be seen in Cumberland. A recent well-boring at Old Colwyn went through loose gravel 9 feet; brown clay, 33 feet; and was stopped in blue clay. In Mr. Pender's brickfield, west of the Station, the pit-section and a well-boring have revealed red brick clay nearly 20 feet; sand and a little fine gravel, 16 feet; boring drill stuck fast under 60 feet of blue clay. In the ballast-pit close to the Railway Station, 30 or 40 feet of sand and gravel lie under a thin covering of red clay, the former (according to Mr. Darbishire, though this I overlooked) being underlaid by brown clay; and the sand rises up from beneath the red clay[2] at a spot south of the road between New Colwyn and Mr. Pender's brickfield. At the New Colwyn Bay Hotel, on the coast, a chip and splinter drift overlies or graduates into the red brick clay, which is underlain by sand and gravel, while the latter rests on a yellowish brown clay (here much obscured by artificial talus), from beneath which the blue clay crops out in the bed of the sea. Between the new hotel and Rhos village the cliff section shows the upper or brick clay resting on sand, be-

[1] Mr. De Rance must have read my articles on the North of England drifts very carelessly, or partly forgotten what he read, when he replied to me in his last article (GEOL. MAG. Sept. 1871), for the reader will easily perceive that I have not said, or intended to be understood, what Mr. De Rance there attributes to me concerning the depth of water in which the blue clay of W. Yorkshire was principally accumulated—the per-centage of the larger boulders in Peel Park, Salford—the conditions existing during the Glacial period, etc. He has strangely, though I believe unintentionally, misstated what I said on the latter subject in the GEOL. MAG. for July, 1871. References to some of Mr. De Rance's arguments will be found incorporated with the present article.

[2] The sand or middle drift everywhere, but especially in the neighbourhood of hills, shows a tendency to raise its head suddenly above the Upper Boulder-clay, so as to appear on the same or even on a newer horizon.

neath which the yellowish brown clay, underlain by the blue, rises up from under the sea. At one point there is a very curious dovetailing of the blue into the brown clay. Some distance seaward from Rhos village, the blue clay makes its appearance at low water. Beyond Rhos village, the yellowish brown clay becomes very conspicuous, and resembles a local subdivision of the Lower Boulder-clay which may be traced along the sea-coast of Cumberland, Lancashire, and Cheshire. It is lost under sand, again shows its face, and further on, beyond Rhos Point, overlies undulating bosses of the blue clay, which there appears in full force.

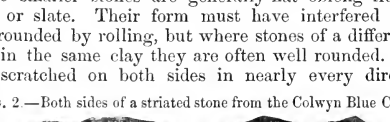
Fig. 1.—Coast-section of a Part of New Colwyn Bay.



2. Lower brown clay. 3. Sand and gravel. 4. Upper red or brick clay.

Peculiarities of the Blue and Brick Clays.—The dark blue, bluish-grey, or sometimes bluish-green clay, is pack-full of small stones, and, in its lower part, larger stones mixed with enormous boulders. It may have been principally derived from the grinding down of the dark Silurian shale or slate which may be found in the neighbourhood. The smaller stones are generally flat oblong fragments of dark shale or slate. Their form must have interfered with their becoming rounded by rolling, but where stones of a different nature are found in the same clay they are often well rounded. They are generally scratched on both sides in nearly every direction, but

Fig. 2.—Both sides of a striated stone from the Colwyn Blue Clay.



seldom distinctly grooved. They look as if they had been "bandied about" while entangled in coast-ice, which finally left them imbedded in the clay. The large boulders[1] reach an average diameter of seven or eight feet near Rhos Point, and consist chiefly of limestone, a gritty rock with veins of calcareous spar, a greenish rock graduating into porphyry greenstone apparently of the Welsh type, Silurian hard shale or slate, volcanic breccia, etc. They may nearly all have come from the neighbourhood; but as I dug out of the blue clay two pebbles of Eskdale granite, and found one of Criffell granite on

[1] They seldom exhibit marks of much flattening through grinding, though some of those which consist of limestone are so irregularly scratched all round, that a gentleman from Chester, who disbelieved in a Glacial period, contended that a party of boys had been disfiguring the boulders in play.

the beach close by, it is clear that, while this clay was in course of being accumulated, an ice-laden current from the far north must have mingled with the local currents of the Glacial sea.[1] The brick clay, or uppermost drift, is usually of a reddish colour. It contains very few large boulders, but a considerable number of small rounded stones, which consist of Lake District porphyry, Eskdale and Criffell granite, Silurian light-coloured grit or sandstone, local limestone, shale, etc., etc. The stones in the brick clay are generally more flattened on one side, deeply and uniformly grooved, and more polished than in the blue clay, so that if any member of the Colwyn drifts is to be exclusively elevated to the rank of a Glacial clay, this brick clay, and not the blue, ought to have the preference; and yet the submarine accumulation of this clay is, I believe, admitted by all geologists.[2]

Between Conway and Bangor.—The Boulder-clay west of Conway seems to be on the horizon of the lower brown member of the northern drift. About Penmaenmawr, sand and gravel may here and there be seen overlying this clay which, near the entrance of the tunnel, attains a thickness of at least 60 feet. It clings to the base of the steep slope of Penmaenmawr hill, is often a real pinel, and contains northern erratics mixed with blocks which must have fallen into it from above when the ice-laden sea beat furiously against the flanks of the Snowdonian mountains. The Boulder-clay thins out upwards under a talus of recent screes which thins out downwards. Between the west end of the tunnel and Llanfairfechan there is an unusually crowded Boulder-scar, which contains stones from the north, including both Eskdale and Criffell granite. At some distance from the sea, above Llanfairfechan church, a brook has revealed a good section of a knoll, consisting (at least partly) of pinel which is a facsimile of what I once saw near Baycliff, Morecambe Bay. One of the numerous included boulders reclined on a thin bed of laminated loam, exactly in the same manner as I had seen near Baycliff. A great thickness of gravel and sand, apparently resting on Boulder-clay, is exposed in the cutting at the east entrance of the tunnel through Bangor hill. At the entrance to the next tunnel on the west side of Bangor valley, the Lower Boulder-clay (of which only patches remain) has been dovetailed into sand and gravel. Here and there on both sides of the valley, above the level of the sand and gravel, this clay, often partaking of the character of pinel, may be seen filling up recesses. Traces of a blue clay may likewise here and there be discovered. The obliquely laminated and contorted sand and gravel near the Station (and which is only a part of an extensive terraced deposit, running southwards

[1] I fear that Miss Eyton, who has made some important contributions to Post-tertiary geology, has been misinformed about the existence of blue clay around Crewe. I could see or hear nothing of it, though I found that some persons gave the name blue clay to the upper red brick clay with greyish-tinged fractures, which there overlies the middle sand and gravel.

[2] It is not, however, the only shell-bearing clay, for shells have been found in the lower brown clay at Llandudno by Mr. Darbishire, and by others in the same clay in Lancashire and Cheshire.

for a considerable distance),[1] reminded me very much of the section I had seen near Lorton, Cumberland. In a pit to the north of the Station, the sand is convoluted similarly to what may be seen near the Coniston Copper Works. Near Upper Bangor I found a small boulder of Eskdale granite which had come out of clay in the neighbourhood; and I afterwards met with two boulders of the same kind of granite on the ridge about a mile south of Bangor New Church.

Around Beaumaris.—North of Beaumaris the sea has encroached on a gradually-swelling knoll, and exposed a section, about 40 feet thick, of upper red clay with scarcely any boulders, but a considerable number of small stones, and a few sand seams. It rests on a brown Boulder-clay (precisely resembling what may be seen on the coast near Workington), which is much harder, and contains many more stones, the lower part being full of large boulders consisting principally of limestone from the adjoining area to the north. Among the stones in general may be found porphyry, felstone, quartz, Cambrian conglomerate, foliated Cambrian rocks, different kinds of granite, etc. Specimens of Eskdale granite may be seen lying on the beach, and I picked two out of the lower or brown clay. Many of the boulders are much glaciated, and those of them which exhibit a flattened side with parallel grooves are generally cross-striated in addition, while the majority of the stones are striated in various directions and often all round. The occurrence of northern drift stones (besides granite, many of the felstones and porphyries, are probably from Cumberland) in this clay, viewed in connexion with their presence along the coast of Caernarvonshire, and their distribution in a S.S.W. direction to a great distance, clearly points to a branch of the great northern drift current which thickly strewed the plains of Lancashire, Cheshire, and Shropshire with Scotch and Cumberland erratics. This current may possibly have split on the N. end of the Snowdonian range of mountains, so as to direct the main course of the floating ice to the S.E.,[2] and a small part of it to the S.S.W.; so that Professor Ramsay, many years ago, was right in believing that Anglesey was once subjected to the action of icebergs from about the N.N.E. point of the compass.

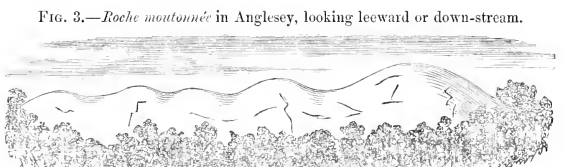
Roches Moutonnées formed by Floating Ice.—On the elevated ground about half a mile S.W. of Bangor New Church, I found striæ pointing N.N.E. On the other side of the Menai Strait, less than a mile from the tubular bridge, the eminence on which the Monument stands, presents a fine example of a *roche moutonnée* rounded and smoothed on all sides except the S.W., which is precipitous and jagged. Though no striæ are visible, the parallel undulations point to about the N.E. as the direction from which the iceberg or icebergs came—

[1] A great part of the Anglesey side of the Menai Strait is covered with stratified sand and gravel. A fine section may be seen in a large pit about half way between Menai Bridge and the Monument.

[2] I have seen no granite on the northern slopes of the Snowdonian hills, or in the Vale of Conway about Trefriw and Llanrwst, but further eastwards it would appear to have been floated some distance into the interior of the country. I have a bit of Eskdale granite which Dr. Williams, of Wrexham, found in a heap of mixed bone and stone débris which had been dug out of Cefn Cave, near St. Asaph.

their sources being probably the higher valleys of the Lake District at a time when the N.W. of England and Wales was deeply submerged. The greater part of the drifts, as may be inferred from the height above the present sea of the sources of their stony contents, must have been accumulated under water too shallow to float large icebergs. Coast-ice, by freezing round and uprooting stones, débris, clay and sand, and likewise by receiving loads of detritus from cliffs and slopes, must be capable of removing much more drift-matter than those icebergs which are the broken-off ends of high level glaciers; but while icebergs alone could have been sufficiently powerful to uniformly grind down and mammilate large rocky projections, the comparative paucity of foreign drift (it is not altogether absent) around these mammilated rocks in Anglesey may thus be easily explained. There is no difficulty in accounting for the preservation of the mammilated form during the rise of the land through the upper part of the tidal range, for these rock-surfaces may have remained covered with drift until just before their final emergence, or they may never have been covered, and yet they may have risen above the sea with their general form uneffaced, for we know that at the present day glaciated rocks stretching from above to beneath the sea on the coasts of Ireland, Scotland, and Norway, have resisted the action of the waves for years; and I am familiar with what some years ago was a highly polished limestone surface on the W. coast of Morecambe Bay, and which, notwithstanding its subjection to the action of waves wielding pebbles, is still so smooth that care is necessary in attempting to walk over it, while some of the striæ can still be dimly discovered. A short distance E. of the Monument there is a well-preserved *roche moutonnée*, which has been glaciated up-hill from about the N.E. The large shallow grooves may still be detected under favourable light and shade, and the much larger parallel undulations are very well defined (see Fig. 3).

Fig. 3.—*Roche moutonnée* in Anglesey, looking leeward or down-stream.

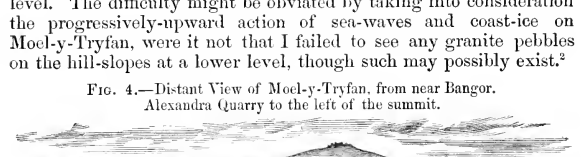


Northern Drift on Moel-y-Tryfan.—On the celebrated Moel-y-Tryfan, five miles S.E. of Caernarvon,[1] mixed local and northern drift may be found. In the 35 feet of irregularly-stratified gravel and sand which rises from the floor of the highest excavation of the Alexandra slate quarry to within a few yards of the rock-crested summit of the hill, there are some large felspathic and porphyritic

[1] Not the stupendous break-neck wedge of felstone, called Y Tryfan, at the head of Nant Francon, from going to which, in search of sea-shells, I lately prevented an eminent *savant*.

boulders (chiefly at the bottom of the section), and many pebbles in the gravel, which may have been worked up from their parent rocks on the N.W. side of the hill by waves and coast-ice as the land was sinking; but a large percentage of the pebbles certainly, and some of the large boulders probably, were derived from the far N. The stones in general are subangular, and consist of felstone deeply weathered white, from the N.W. side of the hill: porphyry partly from the N.W. side of the hill, and partly, I believe, from Cumberland; local slate; several kinds of granite from Cumberland and Scotland; felspathic breccia and ashes from a greater or less distance; quartz and a rock resembling gneiss from the N.W. side of the hill (?); etc., etc. Among the granites there are many pebbles and some good-sized stones of very decided Eskdale and Criffell granite. The latter (which must have travelled no less a distance than 130 miles!) is generally of the same kind as the principal variety found in the drifts of Cumberland, Lancashire, and Cheshire, and is a perfect facsimile of granite now quarried by the Messrs. Newall at Craig Nair, near Dalbeattie.[1] The Eskdale granite embraces several varieties with which I was familiar on the E., W., and N. sides of Eskdale, and between the latter and Wastwater foot; it is likewise of the same kinds as those found in the Lancashire and Cheshire drifts. These granites must have been carried to near the top of Moel-y-Tryfan by rafts of coast-ice when the land was too deeply submerged to permit any granite falling on the surface of glaciers terminating in icebergs. Indeed, there is some difficulty in seeing how even coast-ice could have picked up granite from the Eskdale fells at a height of nearly 1400 feet above the present sea-level. The difficulty might be obviated by taking into consideration the progressively-upward action of sea-waves and coast-ice on Moel-y-Tryfan, were it not that I failed to see any granite pebbles on the hill-slopes at a lower level, though such may possibly exist.[2]

Fig. 4.—Distant View of Moel-y-Tryfan, from near Bangor. Alexandra Quarry to the left of the summit.



The N.W. side of Moel-y-Tryfan is covered with drift varying from loamy sand to hard pinel, being often a mass of subangular or

[1] The Shapfell and Dalbeattie Company are quarrying granite near Dalbeattie of a somewhat different kind with a tendency to run into groups of oblong crystals of felspar of a more or less brownish hue.

[2] Mr. Trimmer, in his Geology (1841), mentions the existence of granitic detritus at eight points between the Menai Strait and Snowdon, but he only specifies Moel-y-Tryfan, and says nothing, so far as I can remember, about the character of the granite.

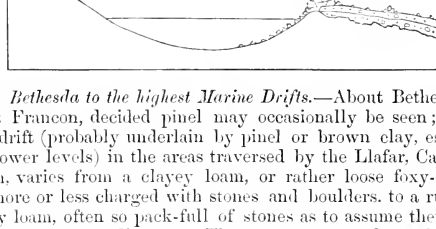
angular stones, mainly felspathic. On the way to Caernarvon there are thousands of large boulders, chiefly porphyry and felstone. Between Caernarvon and Bangor the lower brown Boulder-clay, in places passing into pinel, may be seen in the railway cuttings, and a little blue clay under the brown may be detected near Port Dinorwic.

From Bangor to Marchlyn-mawr.—Between these two places the drift is chiefly the lower brown Boulder-clay, with an occasional greyish tinge towards the surface. It varies from a loose stony and gravelly clay to hard pinel, its general character, however, being nearly the same as that of the lower brown clay of the coasts of Anglesey, Cumberland, Lancashire, and Cheshire. It is generally full of stones and boulders, consisting of directly or indirectly local porphyry, grit, etc. The boulders, though often much rounded at the lower levels, are, in most places, seldom well glaciated. In the valley near Pentir, and elsewhere, this clay is overlain by mounds and plateaux of stratified sand and gravel (excepting where the latter rest on rock), which were probably in part washed out of the clay during the rise of the land,[1] for though a great thickness of sediment can of course only be amassed on a subsiding sea-bottom, yet such comparatively thin, and often sandbank-like, deposits as those under notice would be more likely to be accumulated during emergence. Away from the coasts of N.W. Wales I have nowhere seen sand and gravel regularly and persistently interpolated between a lower and upper Boulder-clay, but in the area under consideration an upper red or foxy-coloured loam or clay may often be seen resting on the brown Boulder-clay. This may be observed at the Turbary W. of the Penrhyn slate quarries, where the lower clay attains a great thickness. From the Turbary the two drifts slope smoothly upwards to the small lake called Marchlyn-mawr, 2000 feet above the sea-level. As Professor Ramsay has suggested, the lake-basin was probably ground out by a glacier; for—though at first it may seem unlikely that a glacier which, on ascending, smooths a projecting boss of rock, leaving its lee-side jagged, should excavate a rock-basin at the bottom of a previously-existing cwm—it must be taken into consideration that in a cwm a short glacier would press "downwards and outwards," that the constant melting of its fore part by the sea would leave the entrance to the cwm comparatively or entirely beyond the reach of the grinding ice, and that the entrance in consequence would remain as a barrier to the lake. The basin of Marchlyn-mawr (like several other lake-basins in North Wales) appears to me as if it had been formed while the land was sinking, and as if it had been partly filled with marine drift, and occupied (after the rise of the land) by a second small glacier, which ploughed out the greater part of the drift and left the striking moraine of angular loose blocks which rests on and conceals the inner termination of the marine drift immediately in front of the

[1] According to Professor Ramsay, the shell-bearing sand and gravel of North Wales was arranged while emerging, or during terrestrial oscillations of level (*Old Glaciers of North Wales*, p. 95).

lake. On the outer side the moraine rises about 20 feet above the drift plateau. On the inner side the top of the moraine is perhaps 40 feet above the level of the lake.[1]

Fig. 5.—Section of Marchlyn-mawr.



From Bethesda to the highest Marine Drifts.—About Bethesda, and in Nant Francon, decided pinel may occasionally be seen; but the visible drift (probably underlain by pinel or brown clay, especially at the lower levels) in the areas traversed by the Llafar, Caseg, and Berthan, varies from a clayey loam, or rather loose foxy-coloured loam, more or less charged with stones and boulders, to a rubbly or gravelly loam, often so pack-full of stones as to assume their colour when viewed from a distance. The stones are angular, subangular, and occasionally rounded. They are either directly or indirectly local, though many of them must have been floated to their present positions irrespectively of the drainage of the country. Comparatively few of the stones are distinctly glaciated. The drift and its stony contents presents the appearance of a heterogeneous accumulation, resulting from the action of sea-waves washing down stones and finer detritus from hill-slopes unfavourable to the exercise of littoral attrition, to lower levels, combined with the dispersive action of stone-freighted coast- or pack-ice. To these agencies we must add the distribution by the sea and floating ice of precipitated moraine débris. Indeed, in many places, as Professor Ramsay has shown, the drift is chiefly spread out moraine-matter, and might be called morainic marine drift. The existence of the drift on slopes, ridges, and watersheds, proves that it could not have been spread out by rains or small mountain streams; while the fact of its stretching up with smooth and flat outline to the higher ends of valleys shows that its distribution could not have resulted from mere sub-aërial glacial action. Moreover, the discovery of sea-shells in what must be regarded as a downward extension of this drift by Mr. Trimmer, and in similar drift near the Turbary by the late Mr. Griffith Ellis, completes the evidence in favour of its accumulation under the sea.

[1] Professor Ramsay believes that this and a number of other lake-basins in North Wales were formed by glaciers which terminated in the sea as the land was rising, that they kept the marine drift out of the basins until they rose above the sea-level, and that the glaciers finally melting the basins were occupied by fresh water. But it may be asked, Did the ewms at the bottoms of which the lake-basins were excavated contain glaciers before the sea (through the movement of the land) had risen up to their levels? or were they only occupied by glaciers after the sea had retreated down to their levels?

In the Cwm Llafar and adjacent areas, this drift may be traced upwards, as Professor Ramsay has shown, to 2300 feet above the sea, and I believe to a greater height. In Cwm Llafar there are terraces "the result of marine denudation during pauses in the re-elevation of the country" (Ramsay). These terraces, so far as I could see, are similar to thousands of platforms and scarps which diversify hill-slopes in various parts of England. They are not so regular, horizontal, or continuous, as those terraces which can be traced to an artificial origin. With great interest, as might be expected, I gazed on the long narrow channel, evidently ploughed out by a glacier in the drift, as Professor Ramsay has shown. In some places it is as fresh-looking as if it had been excavated within the memory of man. Here, as in hundreds of other spots in Wales and the Lake District, we have clear proofs that since the Glacial period even rapid and good-sized *freshwater streams have not lowered the level of the valleys they traverse more than a few feet.*

Professor Ramsay, in his "Old Glaciers of North Wales," p. 101, has drawn attention to a very important fact. Freshwater streams cannot remove (and it follows that they cannot deposit) drift consisting of a mixture of huge boulders with finer detritus. They wash away the finer and lighter matter and leave a concentration of boulders behind. But, it may be remarked, if freshwater could not have accomplished the clearance of boulder drift so strikingly indicated by the long narrow hollow in Cwm Llafar, how could it have transported the blocks, the abstraction of which has left the magnificent mural cliff at the head of the cwm. Freshwater is now assisting frost and gravitation in demolishing this cliff, but it is clearly unable to carry away the talus of fallen fragments.

P.S.—Since the above was written, I have discovered a number of very large boulders, chiefly Eskdale granite, at a height of very nearly 1000 feet above the sea, on Raw Head, one of the Peckforton Hills, which rise suddenly out of the plain of Cheshire.

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